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Friction, Adhesion and Lubrication of Nanoscale Mechanical Systems.

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13. ABSTRACT ***(Maximum 200 Words)***

The equipment purchased by this grant consisted of a variable temperature, ultra-high vacuum compatible scanning tunneling microscope. During the 12 month period in which the grant was in effect, we designed and assembled an ultra-high vacuum chamber to house the microscope, and added this chamber to an existing system. The construction period now complete, and a series of measurements have commenced. These include measurements of the uptake rate of the lubricant TBPP on Fe as a function of temperature, and a series of measurements of the nanomechanical properties of a number of potential lubricants for Micro-Electro-Mechanical Systems (MEMS) applications by means of a combined quartz microbalance/scanning tunneling microscopy technique.

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(1) Final Technical Report:

FRICTION, ADHESION AND LUBRICATION OF NANOSCALE MECHANICAL SYSTEMS.

AFOSR grant # F49620-98-1-0237 Reporting Period: 01 Feb. 1998 – 31 Jan. 1999

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Objectives.
The instrumentation purchased by this grant was intended to enhance the capabilities of an existing apparatus devoted to research on nanotribology. The enhancements allowed molecular-scale studies of friction, adhesion and lubrication to be performed on materials of relevance to MEMS and smaller mechanical systems. In particular, the new capabilities allow friction force microscopy studies of the mechanical and chemical nature of the contact zone of a micromechanical contact, adhesive forces of metal-metal contact regions, and the exploration of the viability of vapor-phase lubricants for performance optimization in nanomechanical systems.

Status of Effort. The reporting period covers 12 months, from 1 Feb. 1998 to 31 Jan. 1999. The following instrumentation was purchased with the monies supplied by this grant: (1) RHK Model 300 scannning tunneling microscope assembly, including variable temperature capabilities: $55,300., and (2) The RHK Model STM 1000 scanning probe control system; $38,800. During the period in which the grant was in effect, we designed and assembled an ultra-high vacuum system to house the microscope, and added this chamber to an existing system. (Figure 1)

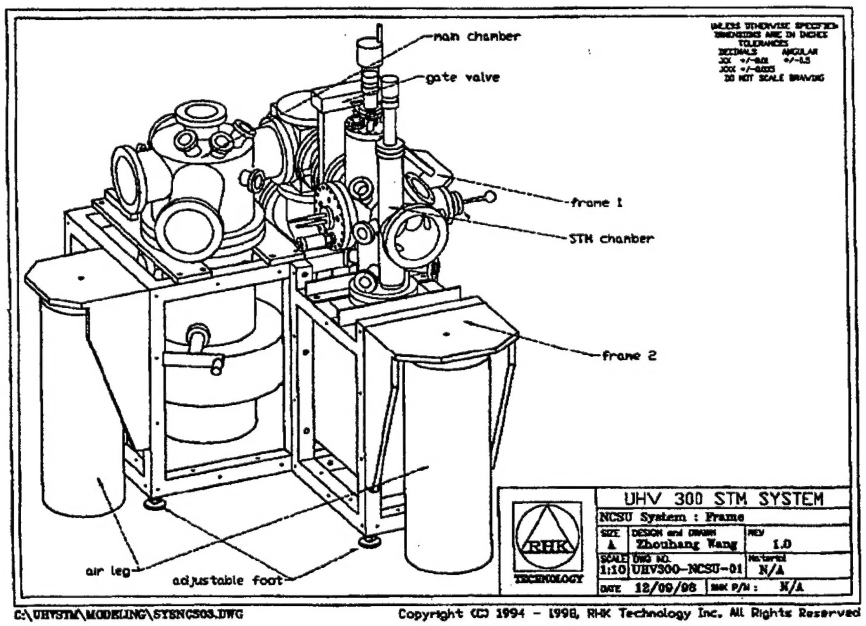

Figure 1: Schematic of the new additions to the existing chamber. The STM addition is now in place and the entire system has been mounted on vibration isolation legs.

Figure 2 depicts a typical image recorded with the new microscope: Atomic gold step edges are easily visible.

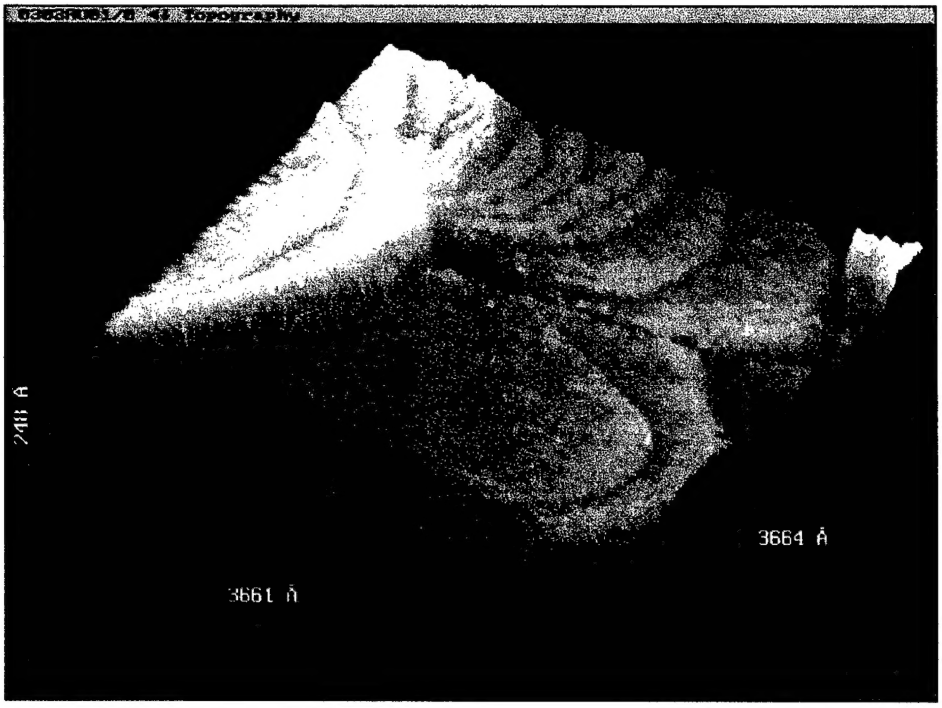

Figure 2: Atomic Step edges of gold imaged with the new scanning tunneling microscope.

The apparatus is now entirely dedicated to our research supported by AFOSR grant # F49620-98-1-02-1, *Vapor-phase Lubricants: Nanometer-scale Mechanisms and Applications to Sub-micron and Rotating Machinery.*
We are currently measuring uptake rates of the lubricant TBPP on metal surfaces at various temperatures. Our studies of combined STM/QCM have demonstrated that a single asperity contact can be made in sliding contact at realistic sliding speeds. Our newest finding is that the tip can be employed for sliding with billions of passes, and then used to image the sliding contact region in areas as small as tens of atoms in lengthscale.This has immediate application to improving the tribological performance of MEMS systems. Moreover, this approach has proven to be far superior to that of an AFM/surface contact. The STM image depicted below was recorded on a silver film which deposited on the surface of a QCM and then exposed to oxygen. The brighter region of the image

corresponds to an area in which the oxygen overlayer was rubbed off, and then the damaged area reimaged. Figure 3 was recorded on an existing STM in our lab with very limited capabilities: In the upcoming year, we plan to implement the joint QCM/STM capabilities to the RHK microscope.

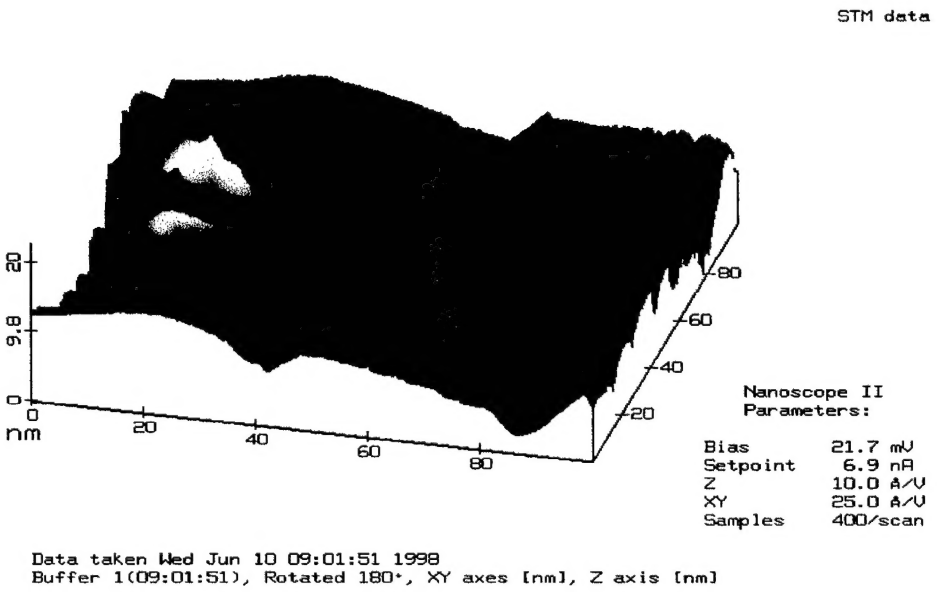

Figure 3: STM image of a silver film which has been in rubbing contact for 10 billion passes with a quartz crystal oscillator.